Nuisance Algae in Lake Michigan:
Causes, Consequences and Management Options

Harvey Bootsma — **UWM Great Lakes WATER Institute**
Stacey Faude
Brian Maybruck
Martin Auer — **Michigan Tech**
Lisa Tomlinson

Dec. 93 Shutdown of NYSEG plant

Jan. 04 Heat exchangers plugged at Kewaunee Power Plant, WI

Aug. 05 Partial shutdown of Pickering nuclear plant (Ontario)

Sep. 05 Partial shutdown of Darlington nuclear plant (Ont.)

OPG estimates clogging due to *Cladophora* has resulted in loss of $30 million over past 12 years.

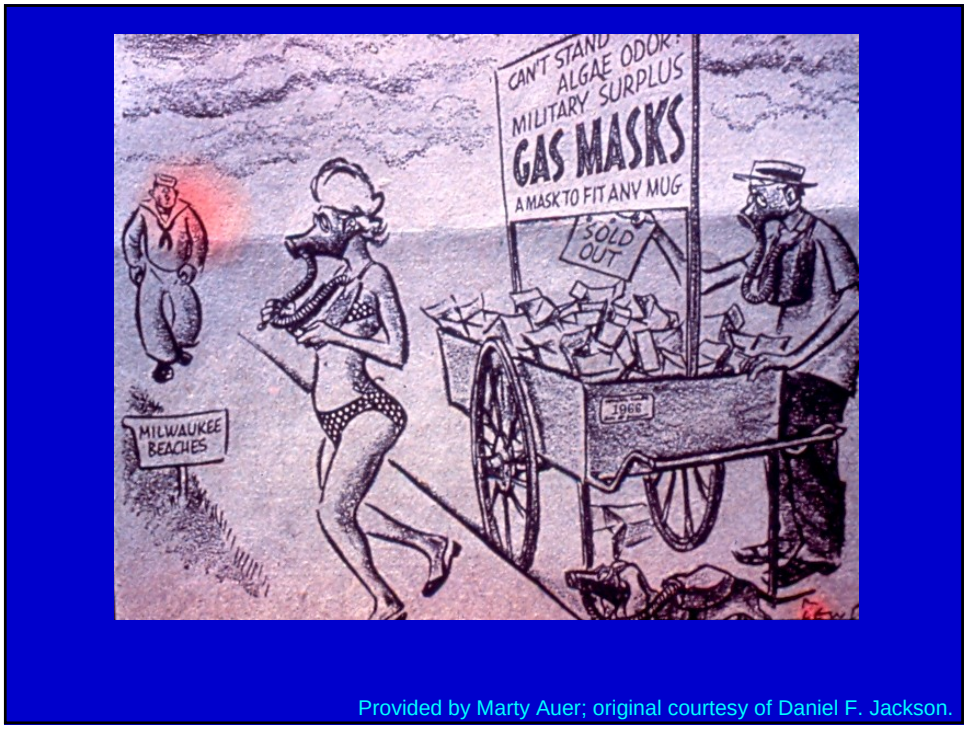
Type E botulism is killing birds. Is *Cladophora* to blame?

The Post-Standard · HERALD-JOURNAL · Herald American

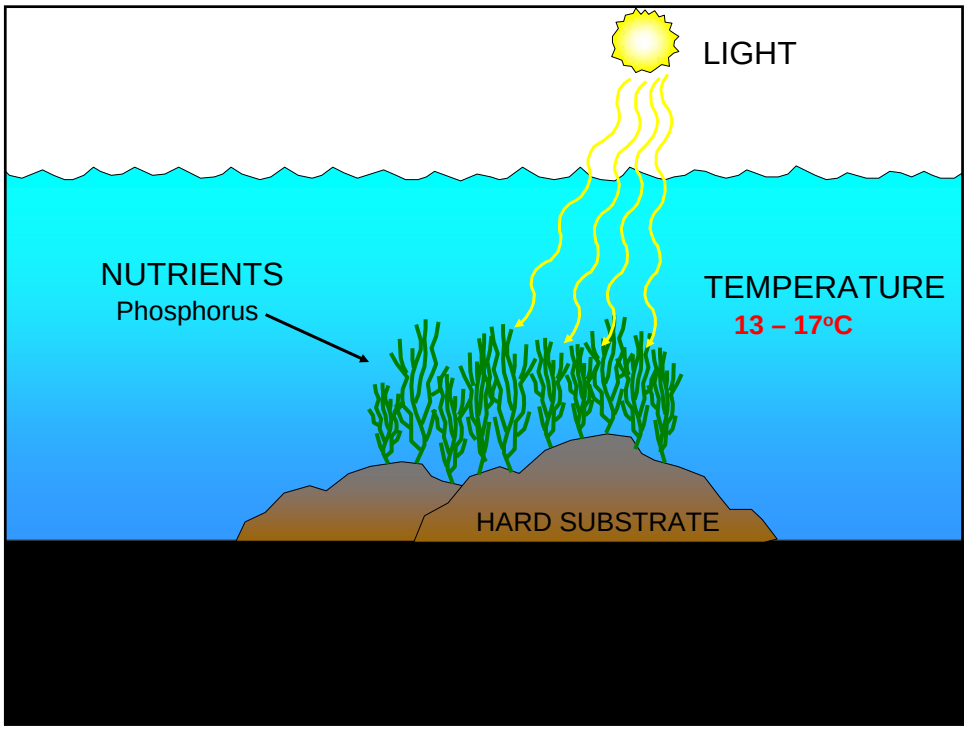
Algae problem along lake clogs senses

PITTSBURGH TRIBUNE-REVIEW

Rotting algae on Lake Erie might carry health hazards, foul odor

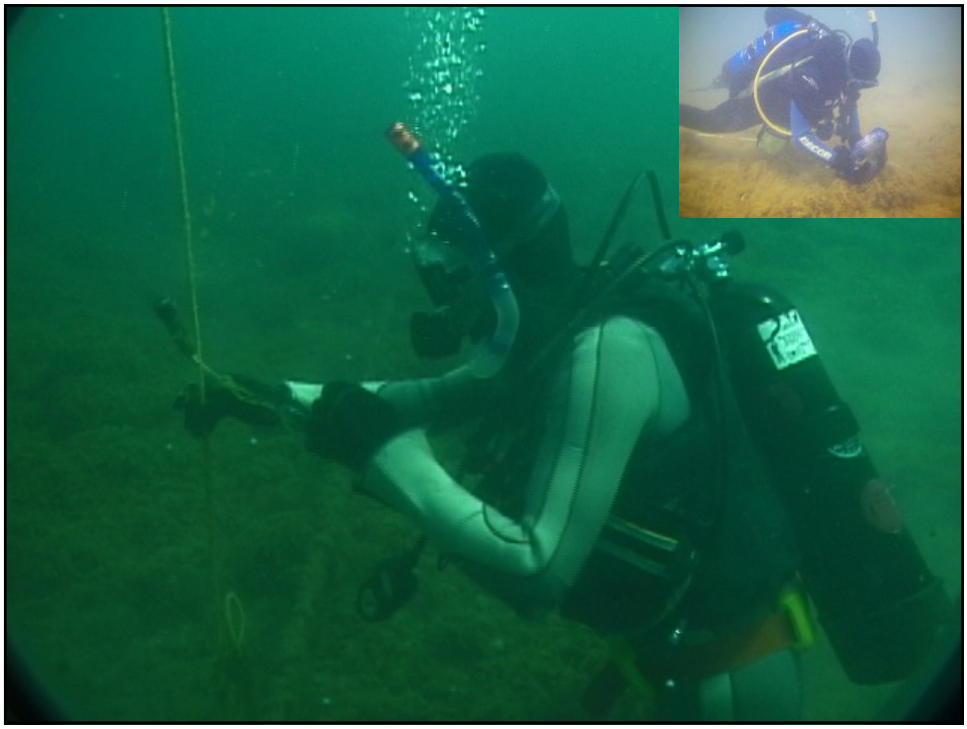


Provided by Marty Auer; original courtesy of Daniel F. Jackson.

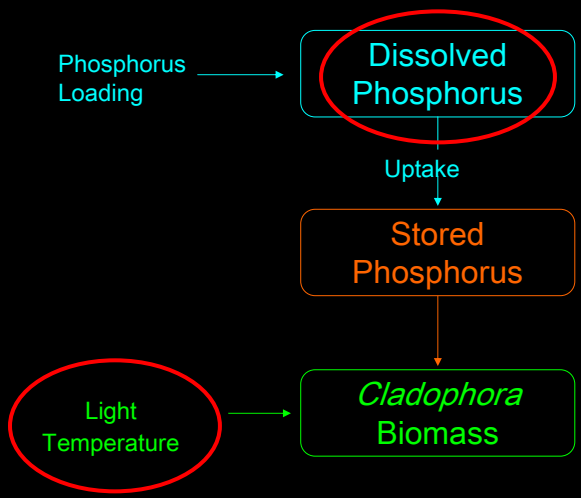


Two Key Questions:

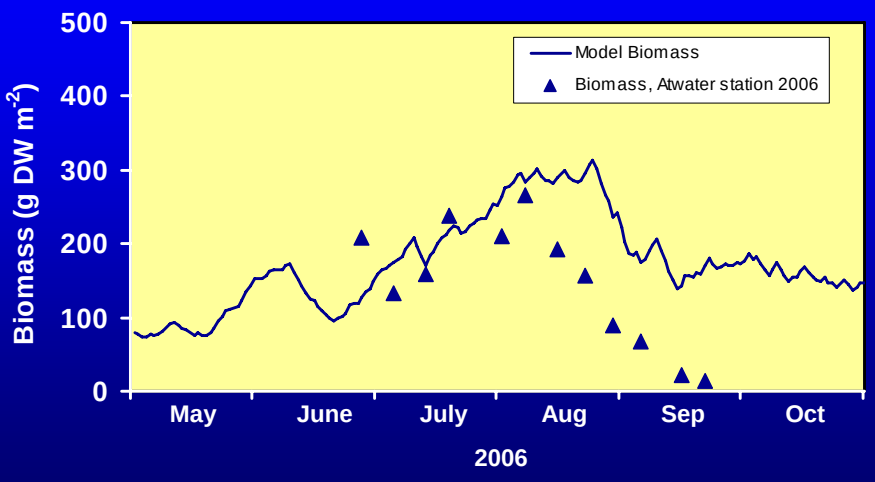
1. **What are the roles of nutrients, light and temperature in controlling *Cladophora* abundance?**
2. **Might the recent increase in *Cladophora* abundance be due to a change in one or more of these factors?**



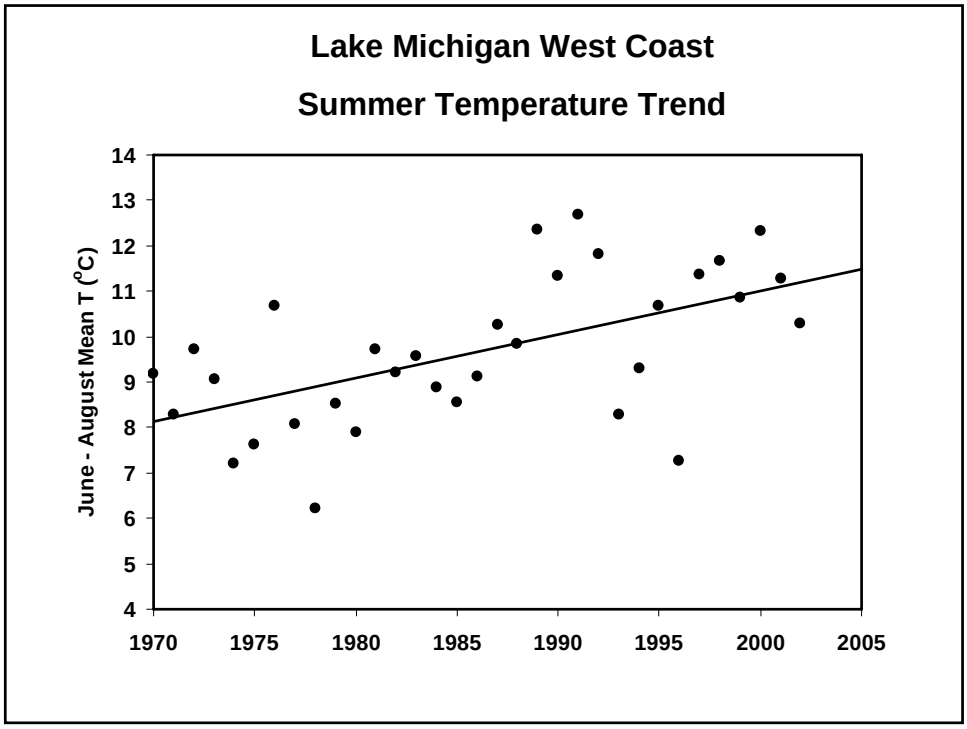
Cladophora Model Conceptual Framework

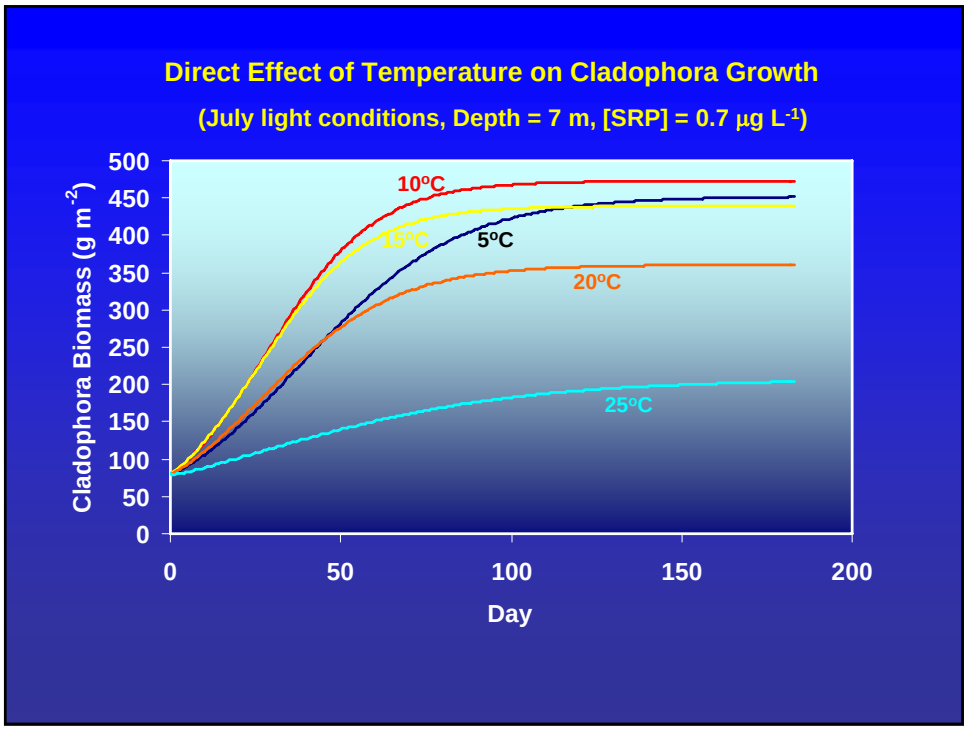


Modeled and Measured *Cladophora* Biomass, Z = 9 m

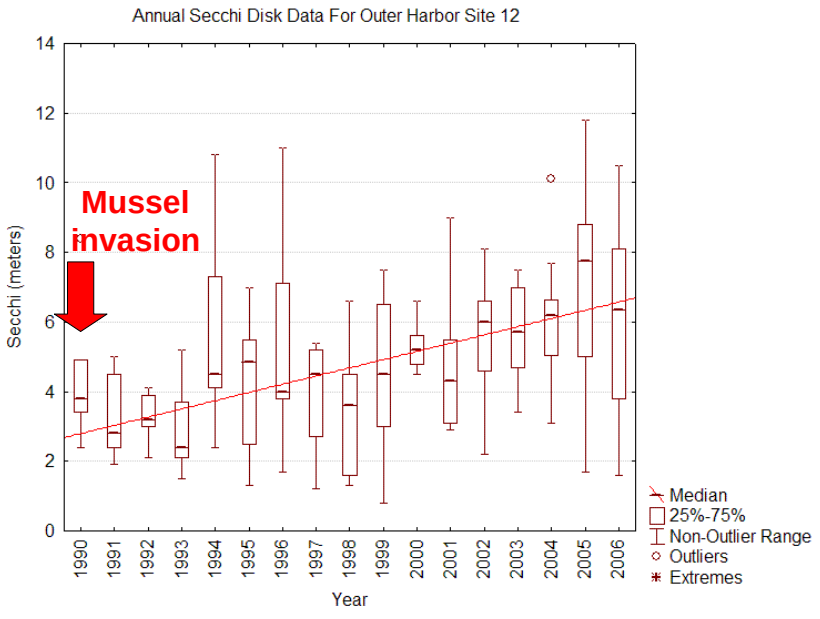


The Role of Temperature


Lake Michigan West Coast
Summer Temperature Trend
June - August Mean T (°C)
14
13
12
11
10
9
8
7
6
5
4
1970
1975
1980
1985
1990
1995
2000
2005


Direct Effect of Temperature on Cladophora Growth
(July light conditions, Depth = 7 m, [SRP] = 0.7 µg L-1)
Cladophora Biomass (g m-2)
500
450
400
350
300
250
200
150
100
50
0
10°C
15°C
5°C
20°C
25°C
0
50
100
150
200
Day

The Role of Light

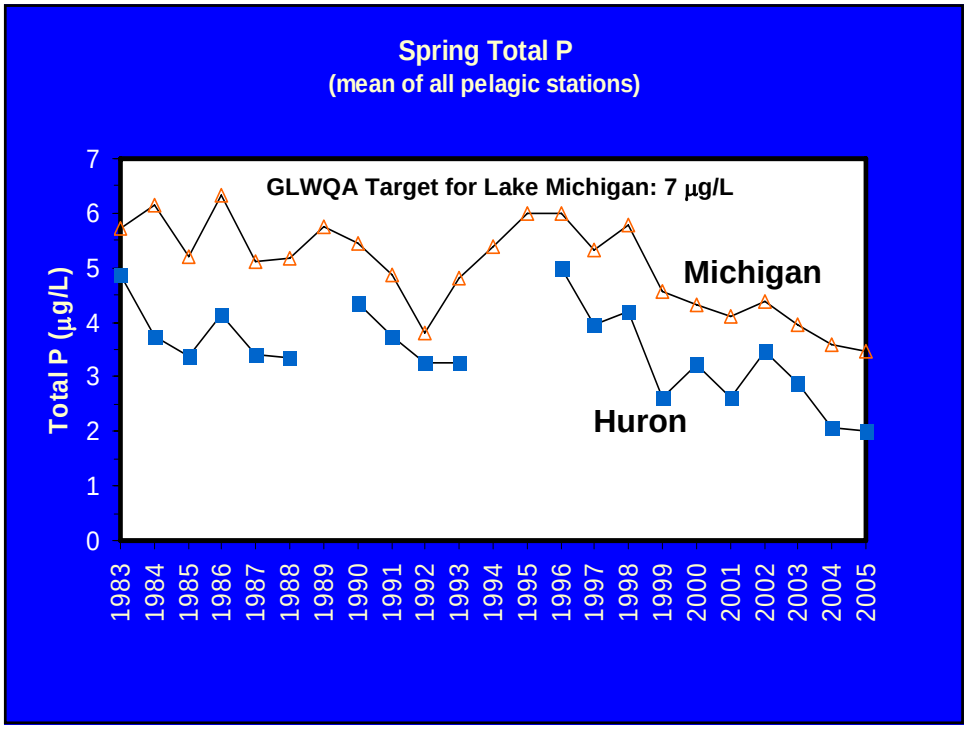


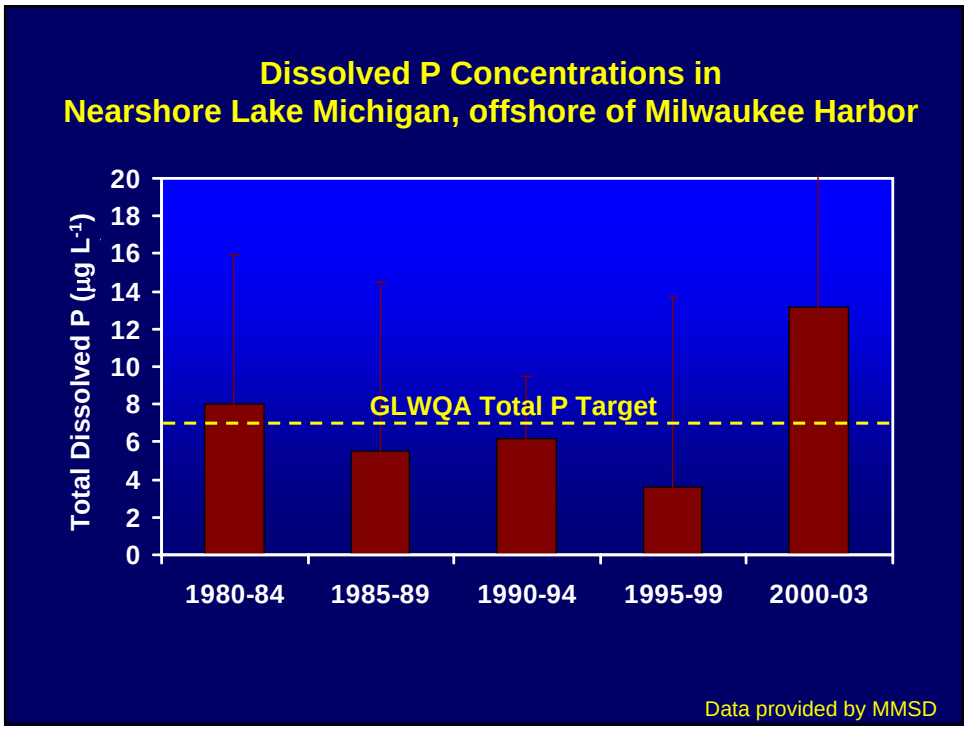
Data provided by MMSD

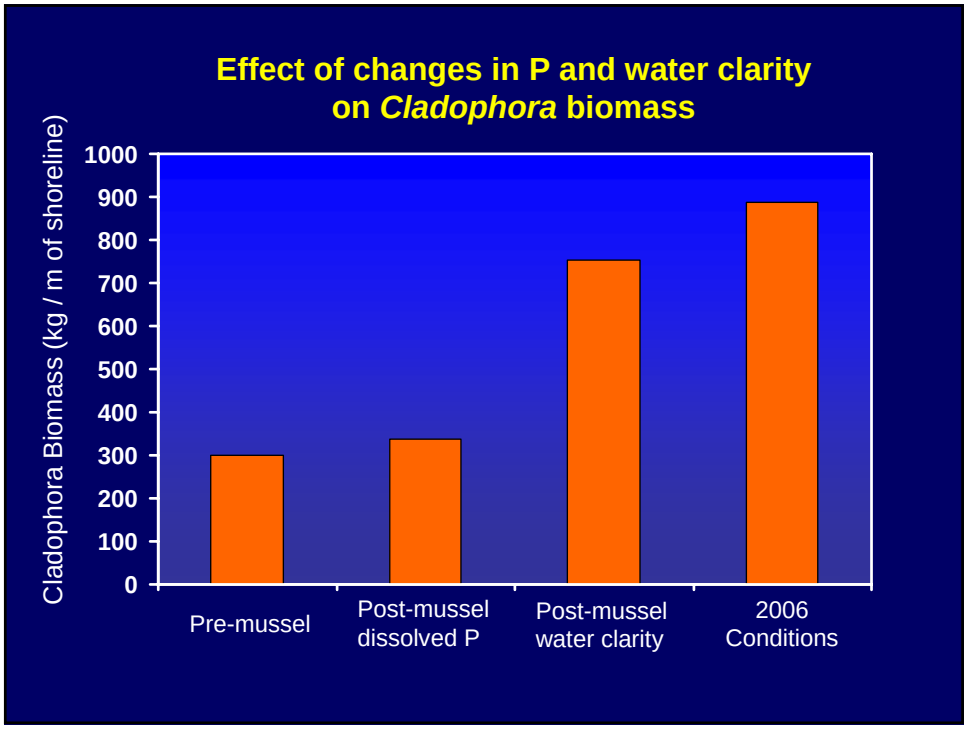
Before

After 30 minutes

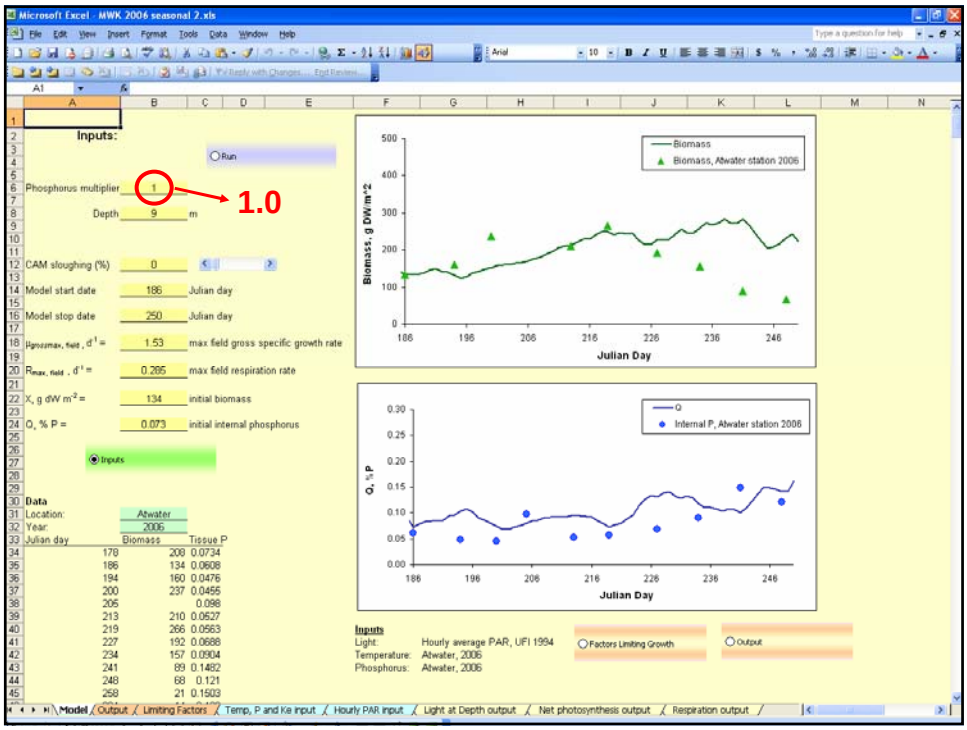
The Role of Phosphorus

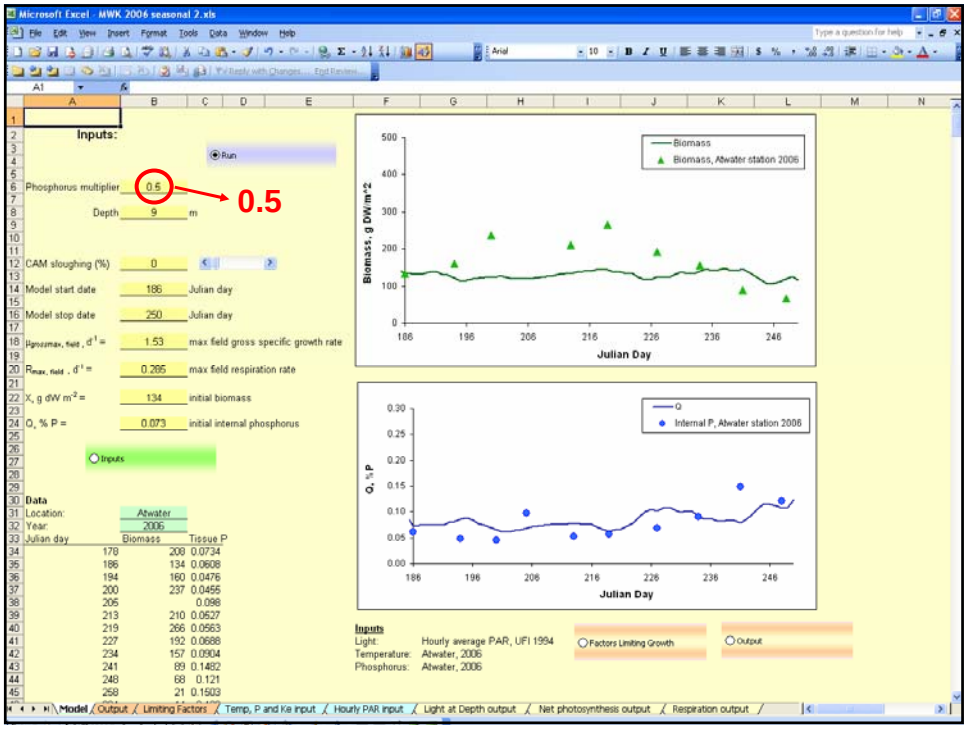

Spring Total P
(mean of all pelagic stations)
GLWQA Target for Lake Michigan: 7 µg/L
Michigan
Huron
Total P (µg/L)
0
1
2
3
4
5
6
7
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005


Dissolved P Concentrations in
Nearshore Lake Michigan, offshore of Milwaukee Harbor
Total Dissolved P (µg L-1)
0
2
4
6
8
10
12
14
16
18
20
GLWQA Total P Target
1980-84
1985-89
1990-94
1995-99
2000-03
Data provided by MMSD


Effect of changes in P and water clarity on *Cladophora* biomass
Cladophora Biomass (kg / m of shoreline)
1000
900
800
700
600
500
400
300
200
100
0
Pre-mussel
Post-mussel dissolved P
Post-mussel water clarity
2006 Conditions

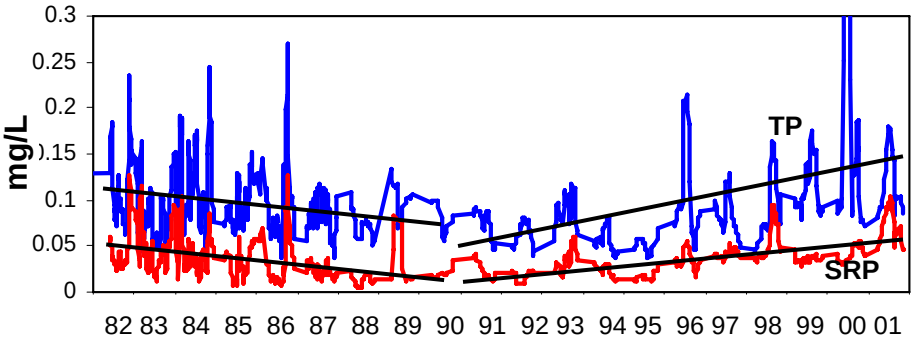
So What Can We Do?



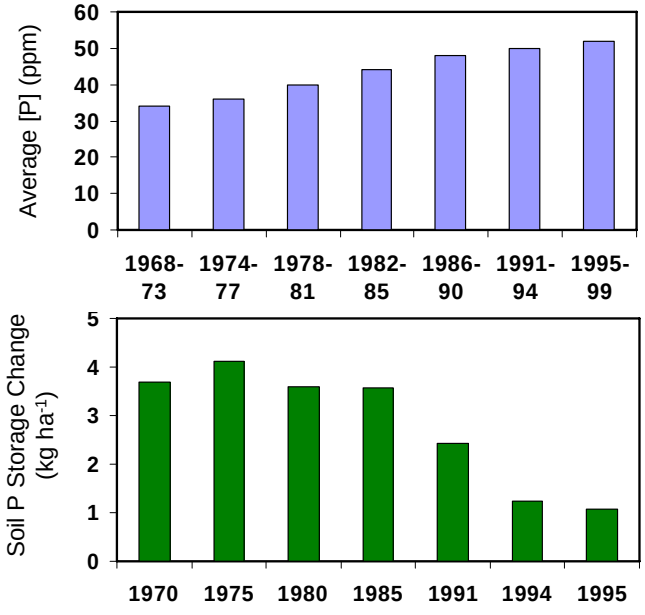

Microsoft Excel - MWK 2006 seasonal 2.xls
Inputs:
Run
Phosphorus multiplier 0.5
0.5
Depth 9 m
CAM sloughing (%) 0
Model start date 186 Julian day
Model stop date 250 Julian day
1.53 max field gross specific growth rate
0.285 max field respiration rate
134 initial biomass
0.073 initial internal phosphorus
Inputs
Data
Location: Atwater
Year: 2006
Julian day Biomass Tissue P
178 208 0.0734
186 134 0.0608
194 160 0.0476
200 237 0.0455
205 0.098
213 210 0.0527
219 266 0.0563
227 192 0.0688
234 157 0.0904
241 89 0.1482
248 68 0.121
258 21 0.1503
Biomass
Biomass, Atwater station 2006
Biomass, g DW/m^2
Julian Day
Q
Internal P, Atwater station 2006
Q, % P
Julian Day
Inputs
Light: Hourly average PAR, UFI 1994
Temperature: Atwater, 2006
Phosphorus: Atwater, 2006
Factors Limiting Growth
Output
Model
Output
Limiting Factors
Temp, P and Ke input
Hourly PAR input
Light at Depth output
Net photosynthesis output
Respiration output


1980

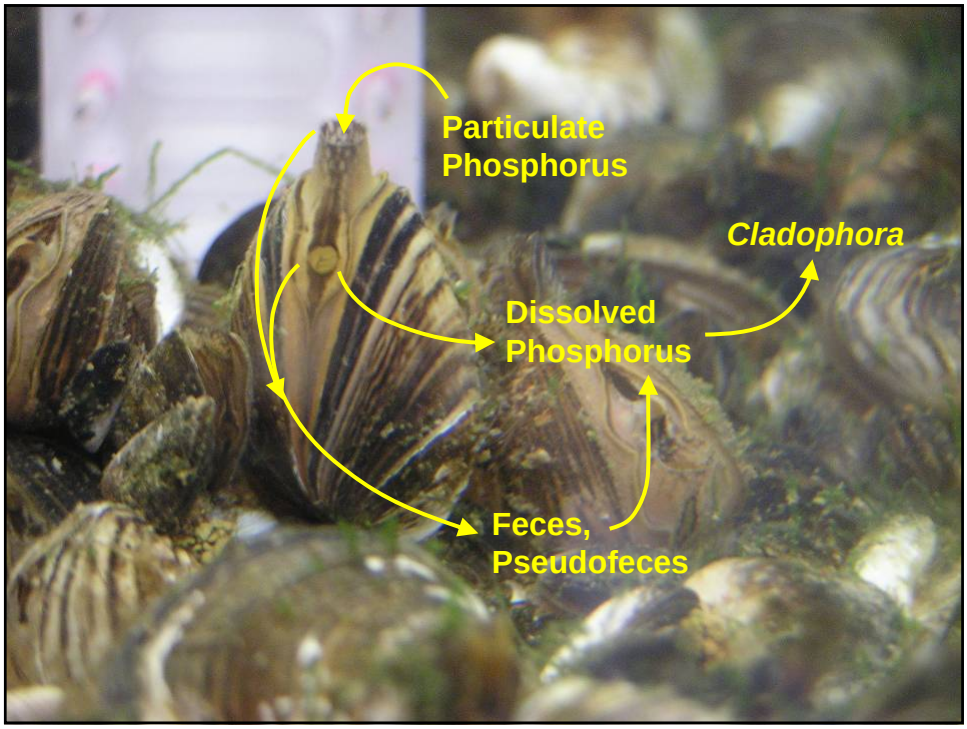
20-Year Phosphorus Trend at River Junction

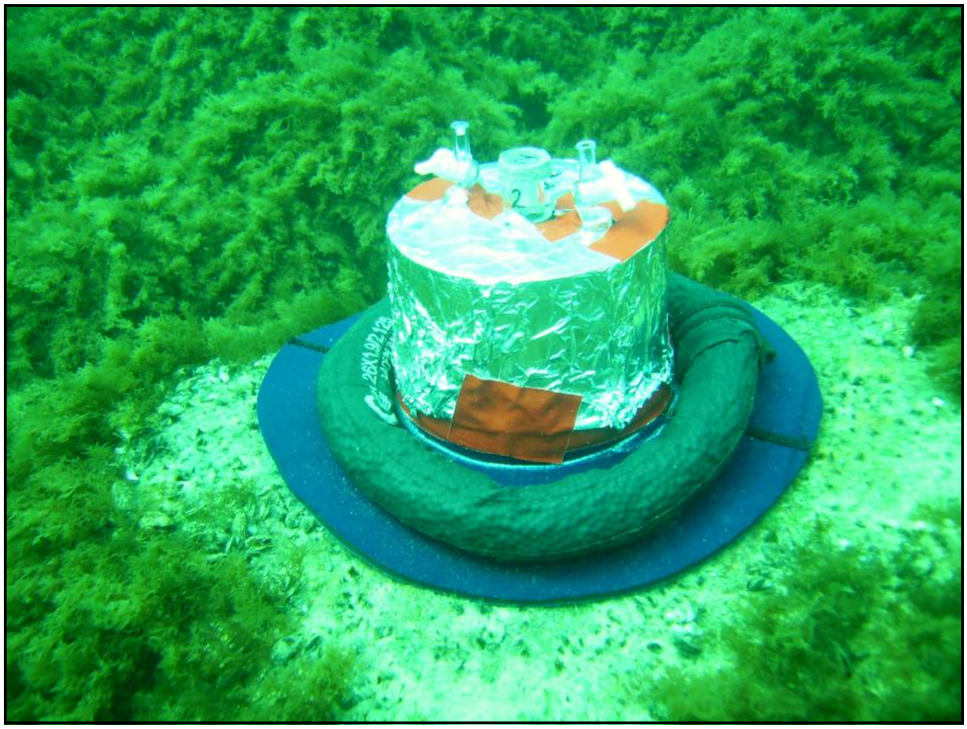


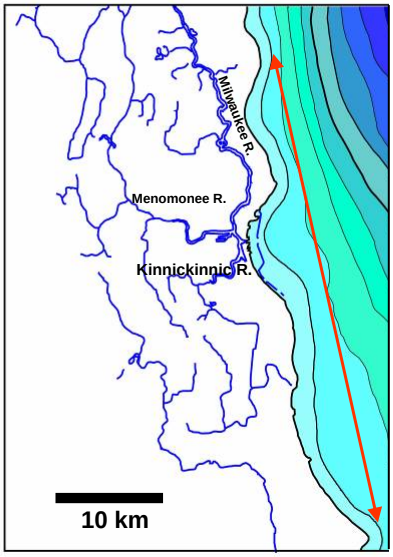
P in Wisconsin Cropland



Bundy and Sturgul 2001


Particulate
Phosphorus
Cladophora
Dissolved
Phosphorus
Feces,
Pseudofeces



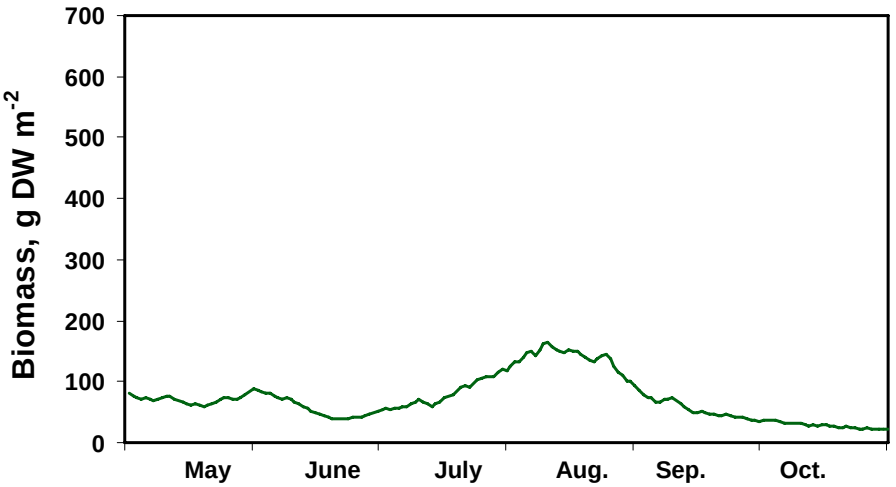


Phosphorus input and uptake for May – July, 2006:

Net *Cladophora* Uptake = 119 mg m^{-2}

River Input = 120 mg m^{-2}

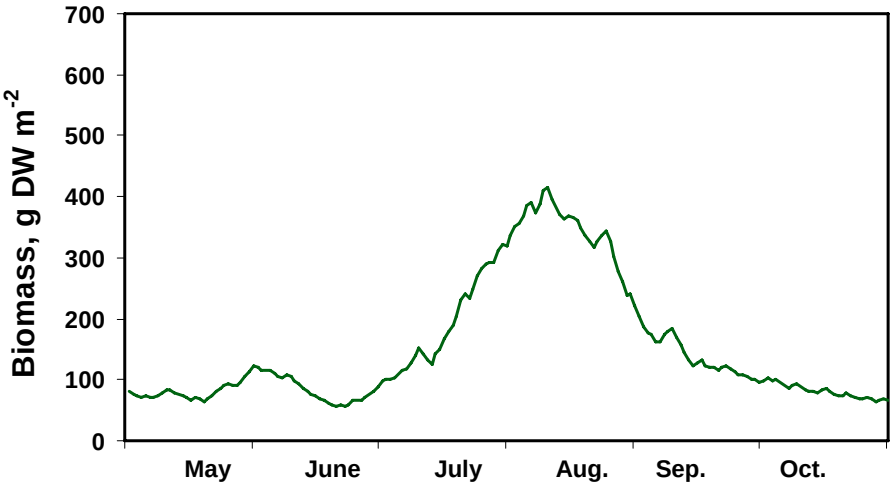
Mussel Excretion = 506 mg m^{-2}



Z = 4 m

SRP = 0.4 μg L^{-1}

Pre-mussel Water Clarity



Z = 4 m

SRP = 1.8 μg L^{-1}

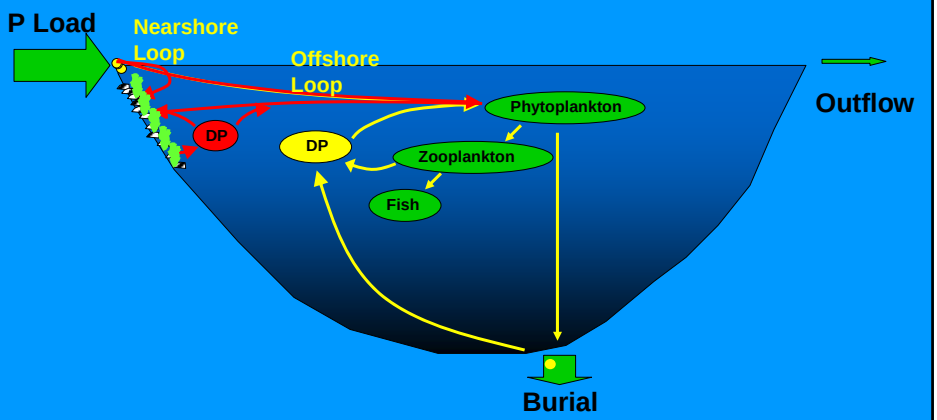
Pre-mussel Water Clarity

Where do mussels get their phosphorus from?

Annual phosphorus load to Lake Michigan is 2,500 T.

Standing stock of P in Lake Michigan is 17,000 T.

The Lake Michigan Phosphorus Cycle



Conclusions

1. Lake water is clearer, which promotes *Cladophora* growth.
2. Mussels may be increasing nearshore dissolved P concentration.
3. We may need to re-consider the nearshore P target of 7 μg L^{-1}.
4. At depths >7 m, 50% P reduction = large decline in *Cladophora*. At shallower depths, the response is less certain.
5. There is lots of P in the lake and in soils. Reducing P in Lake Michigan will take time.

Mendicant monk meditating on 19th Century *Cladophora* beach drift, Gibraltar Island, Put-in-Bay, Ohio.

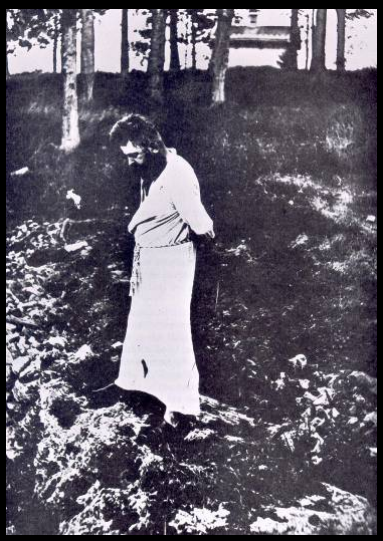


Photo from the J. Cooke Collection, Courtesy of the Ohio Historical Society Library, Columbus, Ohio.

Taken from Taft & Kishler, 1973. Provided by M. Auer